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GREAT LAKES WATER LEVELS SURGE

By Andrew D. Gronewold, Anne H. Clites, Jacob Bruxer, Keith W. Kompoltowicz, Joeseph P. Smith, Timothy S. Hunter, and Cary Wong

The recent 2-year surge represents one of the most rapid rates of water level change on the Great Lakes in recorded history and marks the end of an unprecedented period of low water levels.

Storms and elevated waters on Lake Michigan-Huron led to flooding along Lake Shore Drive in Chicago, Ill. This photo, taken on Halloween in 2014, underscores the combined effects of both a storm event and the recent rapid return of water levels to above-average conditions. October 2014 marked the first time water levels on Lake Michigan-Huron were significantly above monthly average levels since December 1998.

Water levels on Lake Superior and Lake Michigan-Huron (Lake Michigan and Lake Huron are commonly viewed as a single lake from a long-term hydrological perspective), the two largest lakes on Earth by surface area, rose at a remarkable rate over the past 2 years. The recent surge represents one of the most rapid rates of water level change on the Great Lakes in recorded history and marks the end of an unprecedented period of below-average water levels that began in 1998.

Monitoring Water Levels

Routine measurements of Great Lakes water levels have been continually recorded, documented, and communicated to the public since the mid-1800s [*Gronewold et al.,* 2013a] as part of a long-term international partnership between federal agencies including the National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers, Environment Canada, and the Department of Fisheries and Oceans Canada.

The binational Great Lakes water level monitoring program has also served, and continues to serve, as a basis for numerous studies [see, e.g., *Buttle et al.,* 2004; *Mainville and Craymer,* 2005; *Millerd,* 2010] focused on understanding impacts of water level changes on the roughly 17,000 kilometers of Great Lakes coastline across both the United States and Canada [*Gronewold et al.,* 2013b]. These impacts include, but are not limited to, changes in waterway navigability (for both commercial and recreational vessels), hydropower generation, and tourism.

The Recent Surge

Water level data from the long-term binational monitoring program indicate that Lake Superior rose roughly 0.6 meter from January 2013 to December 2014 (Figure 1a), the highest rise ever recorded for that specific 24-month period (January through December of the next year). Similarly, from January 2013 to December 2014, water levels on Lake Michigan-Huron rose nearly 1.0 meter (Figure 1b), a rise nearly equal to the record-setting rise from January 1950 to December 1951.

Historical month-to-month water level changes (Figures 1c and 1d) indicate that the recent extreme 2-year rise on Lake Superior is associated with persistent near- or above-average water level rises for nearly every month. Notable above-average increases occurred from April 2013 to September 2013 and in April, May, and August 2014 (Figure 1c).

Similarly, the recent rise on Lake Michigan-Huron appears to be the result of not only above-average rises in the late spring and summer months (specifically April to June 2013 and April to August 2014) but also above-average rises in both September and October 2014 (Figure 1d). It is very unusual for water levels on Lake Michigan-Huron to rise in the early fall months (in only 11 of the previous 154 years on record, for example, did water levels rise from September to October).

Surge Preceded by Record Lows

Both Lake Superior and Lake Michigan-Huron had been persistently below (or, for brief periods on Lake Superior in 2004 and 2005, extremely close to) long-term monthly averages for a period of roughly 15 years following a rapid decline in the late 1990s [*Assel et al.,* 2004]. During this period, water levels reached record lows for the months of August and September on Lake Superior (in 2007) and for the month of December on Lake Michigan-Huron (in 2012).

In January 2013, Lake Michigan-Huron dropped to its lowest level on record for any month of the year [*Gronewold and Stow,* 2014]. The longest prior continuous periods of below-average water levels on Lake Superior and Lake Michigan-Huron were, respectively, 1921–1928 and 1930–1943.

Water Level Fluctuations in Context

The recent surge in water levels has provided relief to systems and economic sectors stressed by hydrologic extremes. The prolonged period of low water conditions preceding the recent surge, for example, catalyzed demands for new structures designed to reduce flow rates through the St. Clair River and increase water levels on Lake Michigan-Huron [*Gronewold and Stow,* 2014]; the recent surge has changed the context of the debate over the benefits and the urgency of putting these structures in place.

Future Conditions

Internationally coordinated seasonal water level forecasts through the summer of 2015 indicate that monthly average water levels are likely to follow their typical seasonal trends at above-average levels. Beyond that time frame, however, drivers of regional climate variability that can significantly impact regional water budgets and lake water levels remain difficult to predict [*Assel*, 1998; *Rodionov and Assel,* 2003].

The recent rise in water levels on Earth's two largest freshwater surfaces and the preceding period of below-average levels therefore underscore the need for improved understanding of how

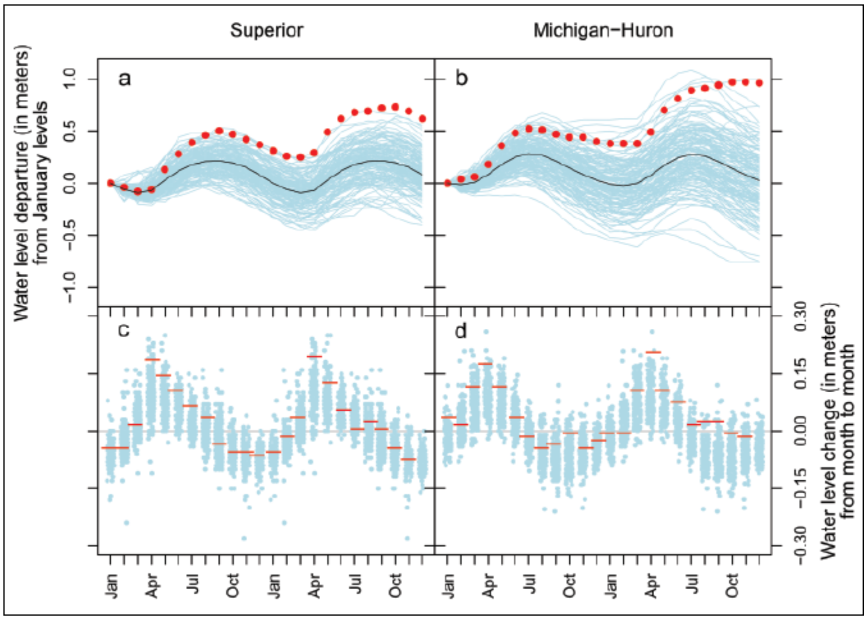

Fig. 1. Seasonal monthly average water levels on Lake Superior and Lake Michigan-Huron. (a and b) Monthly average water level anomalies relative to January levels for each historical 24-month period starting in January and ending in December of the following year (blue curves) as well as the average seasonal water level anomaly (black curve); water level anomalies from January 2013 through December 2014 are presented as red dots. (c and d) Month-to-month water level changes, with red horizontal dashes representing month-to-month changes from January 2013 through December 2014.

long- and short-term climate fluctuations (such as the 2014 Arctic polar vortex deformation [see *Clites et al.*, 2014]) propagate into abrupt changes in the regional water budget and water levels.

Future research focused on understanding interactions between large lake surfaces and atmospheric processes and how those interactions lead to changes in ice cover, surface water temperatures, and evaporation rates may provide insights that support prudent water resource management planning not just in the Great Lakes, but in other regions as well.

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Author Information

Andrew D. Gronewold, Great Lakes Environmental Research Laboratory (GLERL), National Oceanic and Atmospheric Administration (NOAA), Ann Arbor, Mich.; and Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor; **Anne H. Clites,** GLERL, NOAA, Ann Arbor, Mich.; **Jacob Bruxer,** Great Lakes–St. Lawrence Regulation Office, Environment Canada, Cornwall, Ontario, Canada; **Keith W. Kompoltowicz,** Detroit District, U.S. Army Corps of Engineers, Detroit, Mich.; **Joeseph P. Smith,** Cooperative Institute for Limnology and Ecosystems Research, University of Michigan, Ann Arbor; **Timothy S. Hunter,** GLERL, NOAA, Ann Arbor, Mich.; and **Cary Wong,** Center for Operational Oceanographic Products and Services, National Ocean Service, NOAA, Silver Spring, Md.

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